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AUTHORITY

US Army Electronics Command ltr dtd 15 Sep 1971

ECOM-5030
February 1966

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GUN-LAUNCHED VERTICAL PROBES AT WHITE SANDS MISSILE RANGE

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(6) GUN-LAUNCHED VERTICAL PROBES AT WHITE SANDS MISSILE RANGE,

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ABSTRACT

The status of the gun-launched projectile system as a stratospheric sensor vehicle is discussed. The report is based on data obtained at White Sands Missile Range, and at Wallops Island, Virginia, where tests of recently developed hardware show an altitude-obtaining success of nearly 100 per cent. The report reviews the fundamentals of the system, including launcher and propulsion techniques, the flight vehicle, and the payload and expulsion system. It is pointed out that the dispersion characteristics of this vehicle offer new potential for high altitude soundings at sites having limited real estate.

CONTENTS

BACKGROUND

Research into the application of gun-launched vertical probes[1] as atmospheric sounding device vehicles has been conducted during recent years, and the status of such systems has progressed to an encouraging level. The gun probe high-altitude sounding system appears suitable as a routinely operational meteorological device.

Wind sensing payloads, i.e., chaff, parachutes and spheres, have been successfully utilized in the smaller gun-launched systems[2,3] and chemical payloads as high-altitude wind sensors have been flown in larger systems[4]. Telemetry[5,6] units have been developed and successfully flown. Environmental temperature measurements with gun-launched sensors are forthcoming.

The types and sizes of guns used in this development vary from the relatively small 5-inch system, which can project a 20 lb. missile to altitudes of 225,000 ft., to the 16-inch system, which is expected to boost staged rockets to extreme altitudes, and possibly into orbital trajectories. The 5-inch and 7-inch systems are the instruments most applicable to current stratospheric - mesospheric soundings. The U. S. Army Electronics Command, Atmospheric Sciences Laboratory (ECOM-ASL), White Sands Missile Range (WSMR), New Mexico, therefore, has obtained from Ballistic Research Laboratories (BRL), Aberdeen, Maryland, a 5-inch gun system and guidance to establish an operational capability of gun probe applications.

THE WHITE SANDS GUN SYSTEM

This system was installed at WSMR during January 1965. The launch site was selected for proximity to the meteorological rocket launch facilities and shop area. Minimum additional facilities were required to incorporate the gun probe project into the development testing routine. These consisted essentially of a mounting platform, assembly facilities, and a storage magazine for the propellant.

After an initial series of six firings between 2-9 February 1965, suceeding tests were spaced at one to two week intervals to allow time to conduct trajectory and performance studies between firings. Because of the high velocities of the probe, the newly assembled (initially unfired) gun system, and the location of the launch site with respect to the radars, acquisition and tracking were expected to be difficult until some experience was acquired.

Tabular results of the firings to date are presented in Table I. These data show the results of 34 firings conducted at WSMR up to 11 November 1965. While seven of the 34 launchings were not tracked by radar, it will be noticed that all but one of those occurred during the first 13 rounds. It is also evident that of the first 22 flights, altitudes over 200,000 ft. were obtained on only six. Aerodynamic instability in the system was evident, and modifications were undertaken beginning with the firings on 14 September 1965. The next two firings, using models with heavier nose cones, flew successfully. It appeared then that the instability evidenced earlier may have been caused by the center of gravity being too far rearward, and that moving it forward approximately one inch offered promising results. The next model having the new forward c. g. was flown on 4 October 1965, but its performance was not as expected. Coincident with the tests at WSMR, additional tests by BRL were also being conducted

DATE FIRED	ROUND TYPE	MUZZLE VELOCITY	PREDICTED ALTITUDE	RADAR SKIN TRACK	APOGEE	REMARKS
2/2/65	chaff	5100 fps.	250 kft.	no	A259 K ft.	
2/5/65	chaff	-	-	yes	30	Lost fins in tube
2/5/65	chaff	-	-	yes	75	No AGC record
2/8/65	chaff	-	-	no	-	
2/9/65	chaff	-	-	yes	100	
2/9/65	chute	-	-	no	-	
2/18/65	chaff	-	-	no	A235	
2/23/65	chaff	-	-	yes	197	
3/2/65	chaff	5280	265	no	A200	
3/9/65	chaff	5000	235	yes	227	
5/14/65	chute	-	-	yes	221	
5/20/65	chute	-	-	yes	145	Recovered nose cone w/parachute
6/29/65	chute	-	-	no	-	
7/22/65	chute	-	-	yes	219	
8/12/65	chute	4500	175	yes	84	Missile recovered intact from impact crater; 14 ft. below surface.
8/18/65	chute	5280	260	yes	134	
8/23/65	chute	5100	245	yes	217	
9/1/65	chute	-	-	yes	30	Nose ejected on launch
9/2/65	chute	-	-	yes	152	
9/8/65	acoustic source	4840	135	yes	118	
9/8/65	ballistic	5000	235	yes	86	No AGC record
9/11/65	acoustic source	-	-	yes	144	
9/14/65	ballistic	4920	230	yes	233	
9/16/65	ballistic	-	-	yes	221	
9/28/65	chute	4840	220	yes	30	Nose ejected at launch
10/4/65	ballistic	4700	200	yes	98	
10/5/65	chute	-	-	yes	30	Nose ejected on launch
10/11/65	ballistic	4740	200	no	-	No flight data available
10/13/65	balfistic	-	-	yes	217	
10/28/65	acoustic source	-	-	yes	235	
10/28/65	acoustic source	5170-	142	yes	200	
10/2[illegible]/65	acoustic source	4840	125	yes	132	Event at 80 K ft.
10/28 65	acoustic source	5000	135	yes	189	Event at 50 K.
11/10/[illegible]	chaff	4840	245	no	223+	Chaff payload located at 223 K ft. 2 min. after scheduled ejection.

1--+ Acoustic source rounds were scheduled for a 40 seconds event ,thus affecting the trajectory.

2--- Indicated apogee was computed from acoustic impact data.

3--- Partial skin track. Missile still ascending when lost. Chaff payload detected after 7 minutes.

4--- Indicates AGC record showed missile unstable on launch.

Table I Tabular results of developmental firings of the 5-inch gun-probe system at WSMR. Only the last firing on the table (10 November 65) was of the latest fin design that has demonstrated over 93 per cent altitude-success.

to solve the instability problem. To obtain maximum altitude, all earlier models were constructed so as to fly fin-stabilized, with no rotational motion. It was suggested that a certain amount of roll was developing on launch, and was evidently coupling with the pitch frequency of the model, resulting in an unstable flight. The work at BRL led to the design of a fin that would spin the vechicle at approximately 12 revolutions per second and overcome the likelihood of the pitch-roll couple. Fourteen of these fins were constructed and 13 were fired at the National Aeronautics and Space Administration (NASA) test facility, Wallops Island, Virginia, by BRL. Of these 13 rounds, 12 attained altitudes in excess of 200,000 ft from a sea level launch site when fired at an 80° quadrant elevation (QE). The model that did not attain this altitude contained an experimental nose cone which failed and caused a low flight. It was evident, however, that the new type fin provided the desired stability. The remaining spin-type fin was used at White Sands on 10 November 1965, and, while the actual altitude obtained is not known precisely (computed to be approximately 250,000 ft from acoustic impact data), the chaff package was detected at 223,000 ft two minutes after planned ejection, and it is apparent that the missile flew as planned. Thus it appears that acceptable performance of the gun system for placing a payload at altitude has been obtained.

The flights at White Sands utilizing the earlier model vehicle with non-spin fins, and excluding the acoustic source rounds, were 50 per cent successful regarding maximum altitude as the criterion.

The characteristics of the gun system, and the nature of the problems encountered to date can be categorized in three groups: the launcher and propulsion system, the flight vehicle system, and the payload.

PAYLOADS

While payload deployment has been restricted, this function has not been emphasized, pending correction of the aerodynamic parameters and obtaining satisfactory trajectories. To date, most effort has gone into flight performance of the basic gun probe vehicle and launcher performance. Acceptable payloads are operational, but refinements are desired from the meteorological standpoint. Chaff payloads are of such nature that it is difficult to damage them on ejection and, thus, an acceptable wind measuring system exists. However, the inherent disadvantages of chaff are present, and it is desirable to perfect the parachute system for reliable performance. Many parachutes have been ejected and tracked for wind data at Wallops Island, and the fundamentals of chute ejection and deployment from the gun probe system have been established. Refinements to prevent the tearing or burning of the parachute (evidence of this is present on most recovered parachutes) are being made, and the parachute will soon be an acceptable payload for the gun probe system. Payload packaging and deployment will comprise the next major phase of development at WSMR, with emphasis on telemetry payloads to follow.

The acoustic source payload consists of a 180 gm charge of photoflash material which yields a 1×10^{8} C_p intensity light source and sufficient acoustis energy to be detected at several ground receiving stations on the range. It is designed to fit in the payload cavity, and can be ejected and ignited with the conventional expulsion charge. The light source serves to accurately identify the point in space of the source with ballistic cameras. Approximate event time is predetermined and the flash is initiated with a pyrotechnic time delay fuse carried in the projectile.

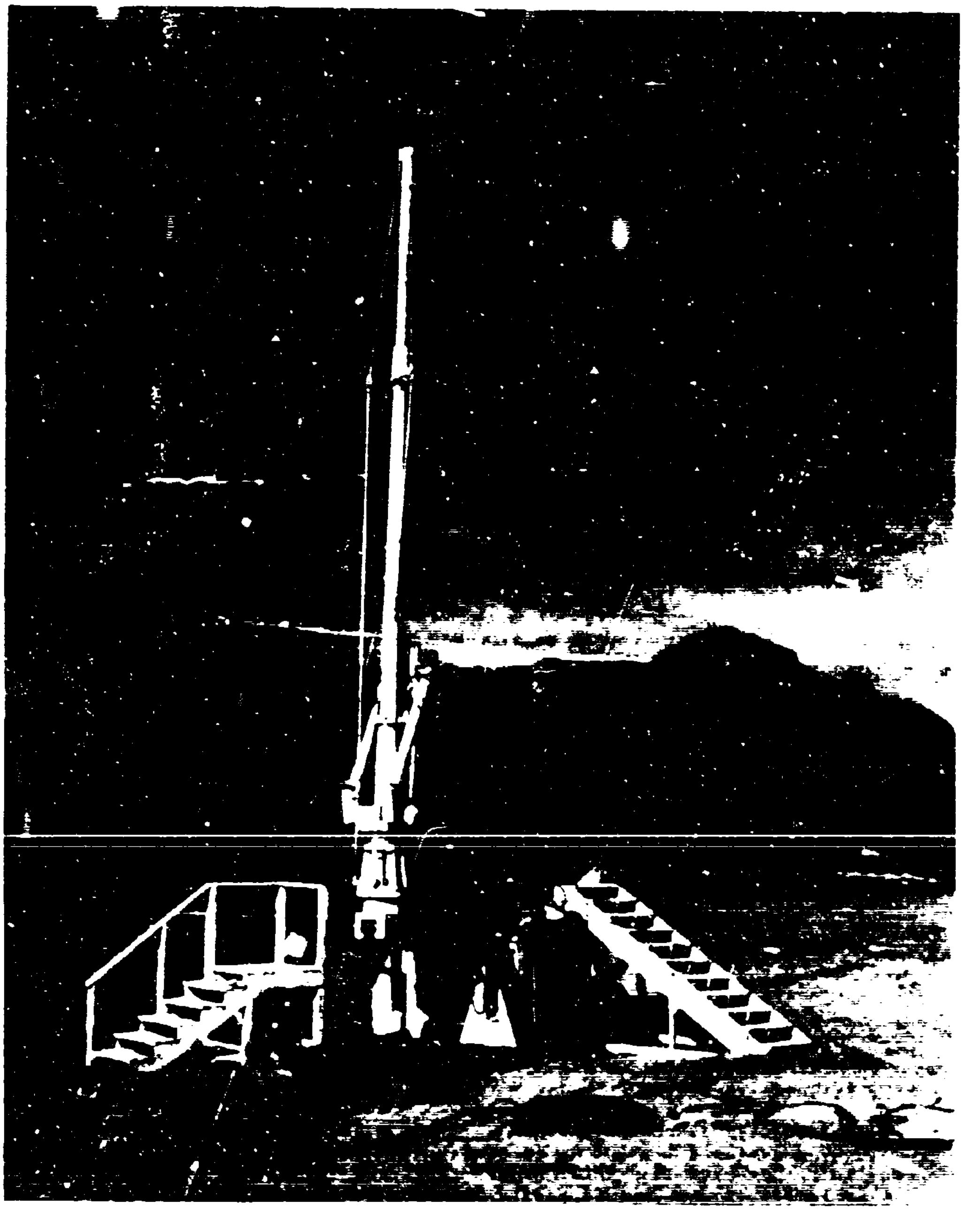

Figure 1 The 5-inch gun-probe system at WSMR. The gun is mounted on a 30° inclined platform to allow near-vertical firing angles for stratospheric sampling.

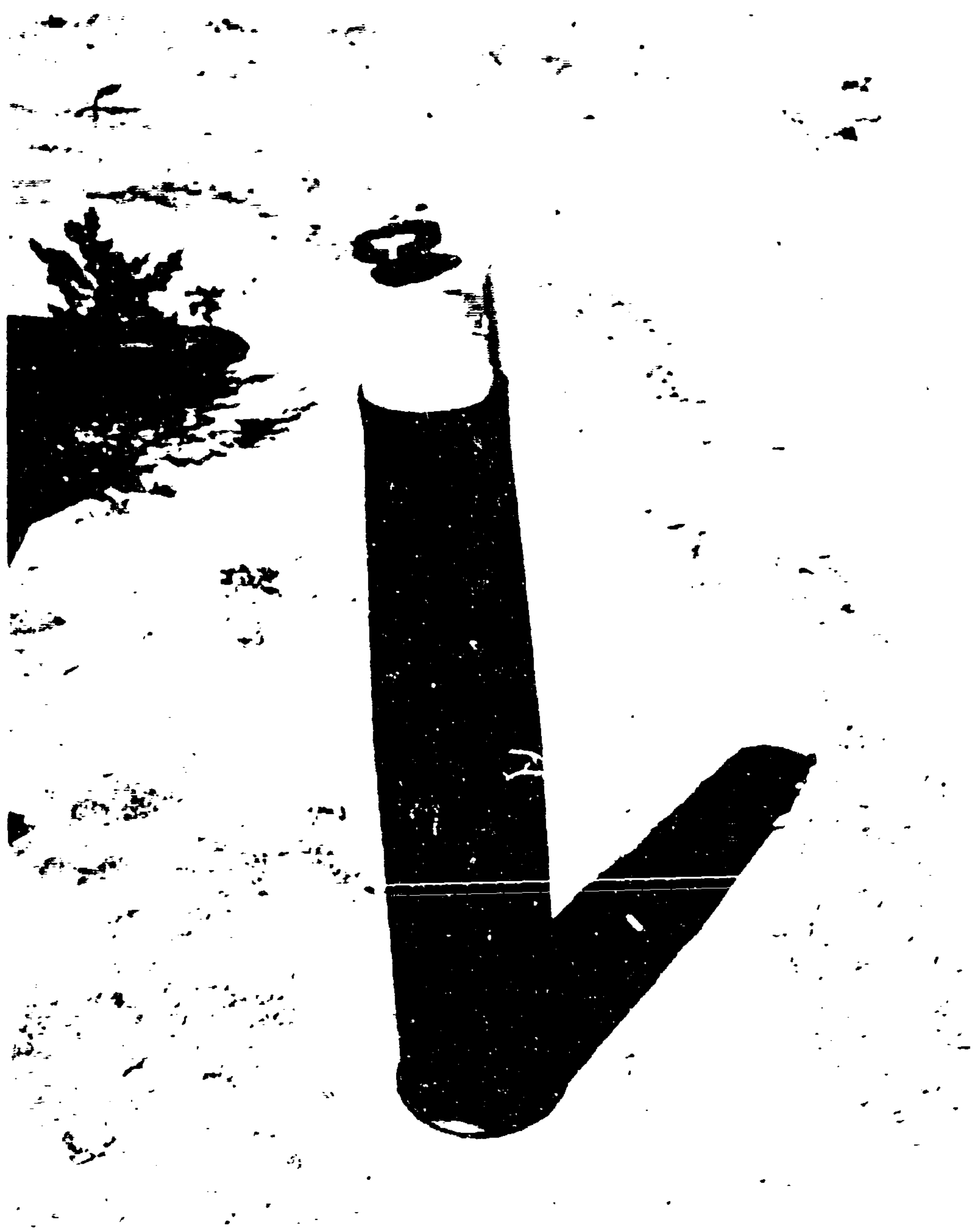

Figure 2 A standard 120 mm cartridge case loaded with a triple-web mixture of M-17 gunpowder and a sheet additive coolant constitute the propellant for the gun-probe vehicle. Powder temperature is monitored with a probe thermometer which is removed immediately prior to loading.

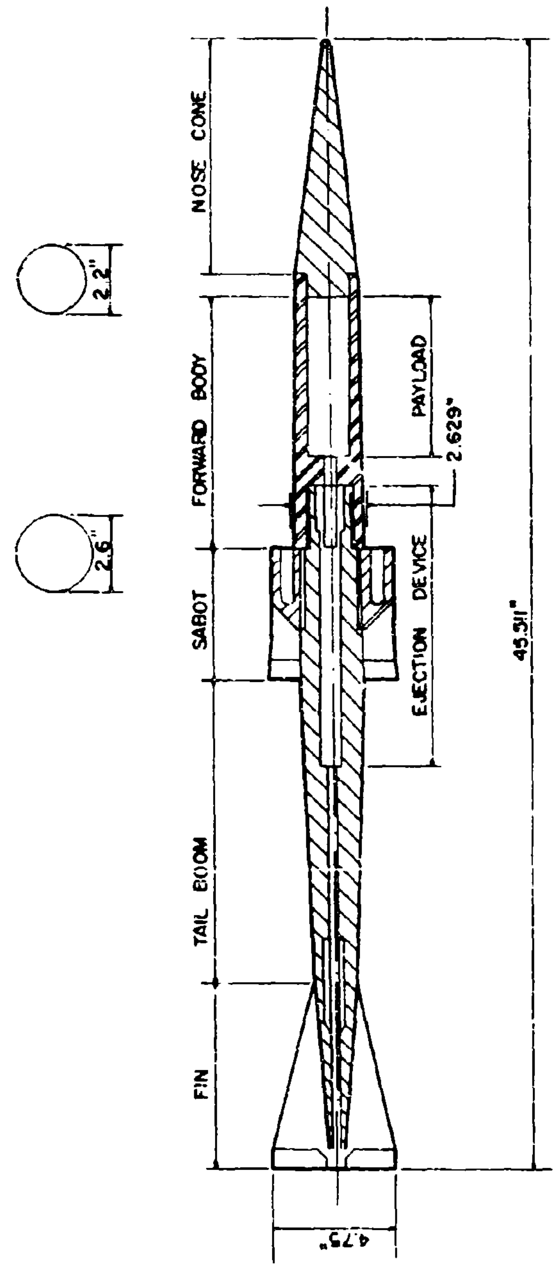

Figure 3 Drawing of the 5-inch gun-probe vehicle. The sabot pieces carry the the missile through the barrel, and are drag separated on leaving the muzzle.

LAUNCHER AND PROPULSION

The launcher system consists of a 120 mm T123 gun (Fig. 1) with the tube smooth-bored. The total length of the tube with a 10 ft extension is approximately 33 ft. The purpose of the tube extension is to allow acceleration over the greatest distance possible. Desired muzzle velocities, on the order of 5000 ft/sec, are unattainable for the missile in a shorter tube, and even with the tube extension maximum g-loading on the missile may approach 60,000 g's. The gun is mounted on a 155 mm carriage and recoil system to accommodate the additional weight and recoil loading. This assembly of the gun and carriage will permit elevations of approximately 65 degrees. Since near-vertical soundings are desirable, the entire gun system is mounted on a support platform with a 30 degree table (also Fig. 1). This is a somewhat bulky arrangement, and future models will probably be assembled on girder type mounts that will permit 0^o to 90^o elevation and eliminate much of the bulk of the system.

Propulsion is obtained through a nonconventional, but uncomplicated, type charge. A triple-web mixture of M-17 gunpowder is blended for proper burn rate and loaded into a standard 120 mm cartridge case. This cartridge is a separate-loading type charge (Fig. 2). Breech pressures generated in the firing are on the order of 55,000 psi. While this pressure is higher than the usual recommended pressure for field operations, it is well below the 90,000 psi tested pressure for the breech.

The principal problem introduced by excess pressure is that of barrel erosion. This problem has been largely overcome by the development of an additive that keeps the chamber temperature down. This addition consists of a titanium dioxide chalk in sheet form that is rolled and inserted into the cartridge case and extends into the barrel approximately six inches beyond the forward end of the case.

FLIGHT VEHICLE

The flight vehicle (Fig. 3) is a subcaliber fin-stabilized projectile that is approximately 45 inches long and weighs about 20 lbs. The maximum body diameter is 2.6 inches, and the fins are slightly smaller than the gun-barrel diameter.

The payload cavity is located in the forward body of the vehicle. The cavity is approximately 1.8 inches in diameter and 7 inches deep. The passive payloads have been entirely packaged in this cavity, while some telemetry payloads have utilized the cavity for power and component storage and the nose cone as an antenna housing. Payload separation is achieved by a gravity-activated pyrotechnic fuse, mounted in the midsection of the missile, that ignites a powder charge and ejects the payload housing through the forward section.

The vehicle is held in the barrel by a sabot cluster that serves both as stabilizer and as a pressure seal. The sabot rings are made up of quarter and half sections, and are quickly drag separated on leaving the muzzle (Fig. 4).

The loading of the vehicle into the gun is performed with a hydraulic jack and loading fixture (Fig. 5) which enables the vehicle to be positioned in the barrel with hydraulic pressure of approximately 1500 psi. After the missile is loaded into the barrel, the hydraulic system is rotated out of the way, the propellant charge is loaded, and the breech closed. The firing pin is then attached using normal procedures. Firing can be performed either electrically or by lanyard if field conditions should so dictate.

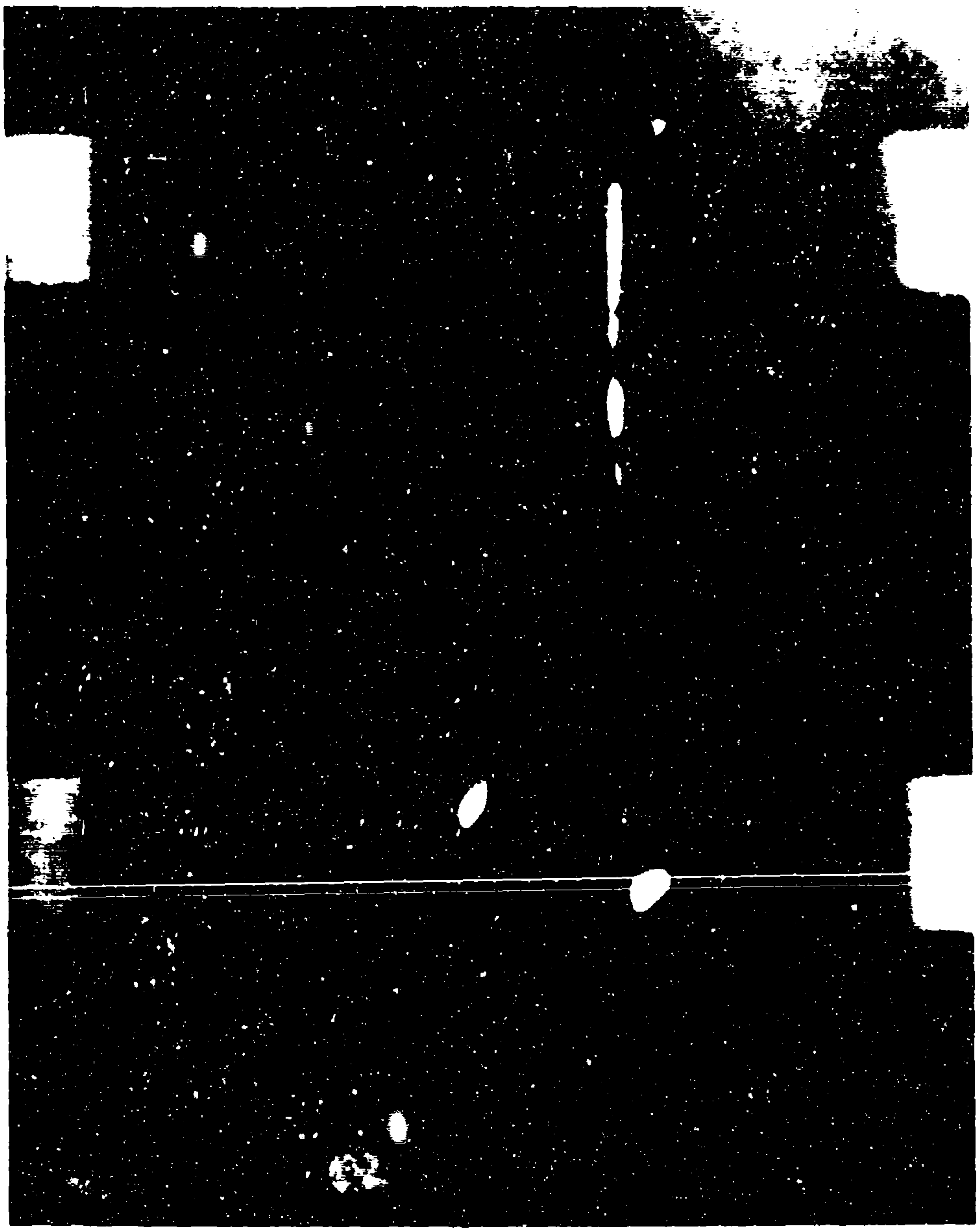

Figure 4 The 5-inch gun-probe vehicle in flight. The vehicle, moving at a velocity in excess of 5000 ft/sec and photographed with an image motion compensation camera, is 80 feet from the gun muzzle. Note the sabot pieces have separated and fallen behind the missile.

Figure 5 The hydraulic jack used for placing the vehicle into position in the barrel. The fins of the missile slide into the slots in the jacking fixture, the front base of which rests against the sabot cluster and seats the projectile.

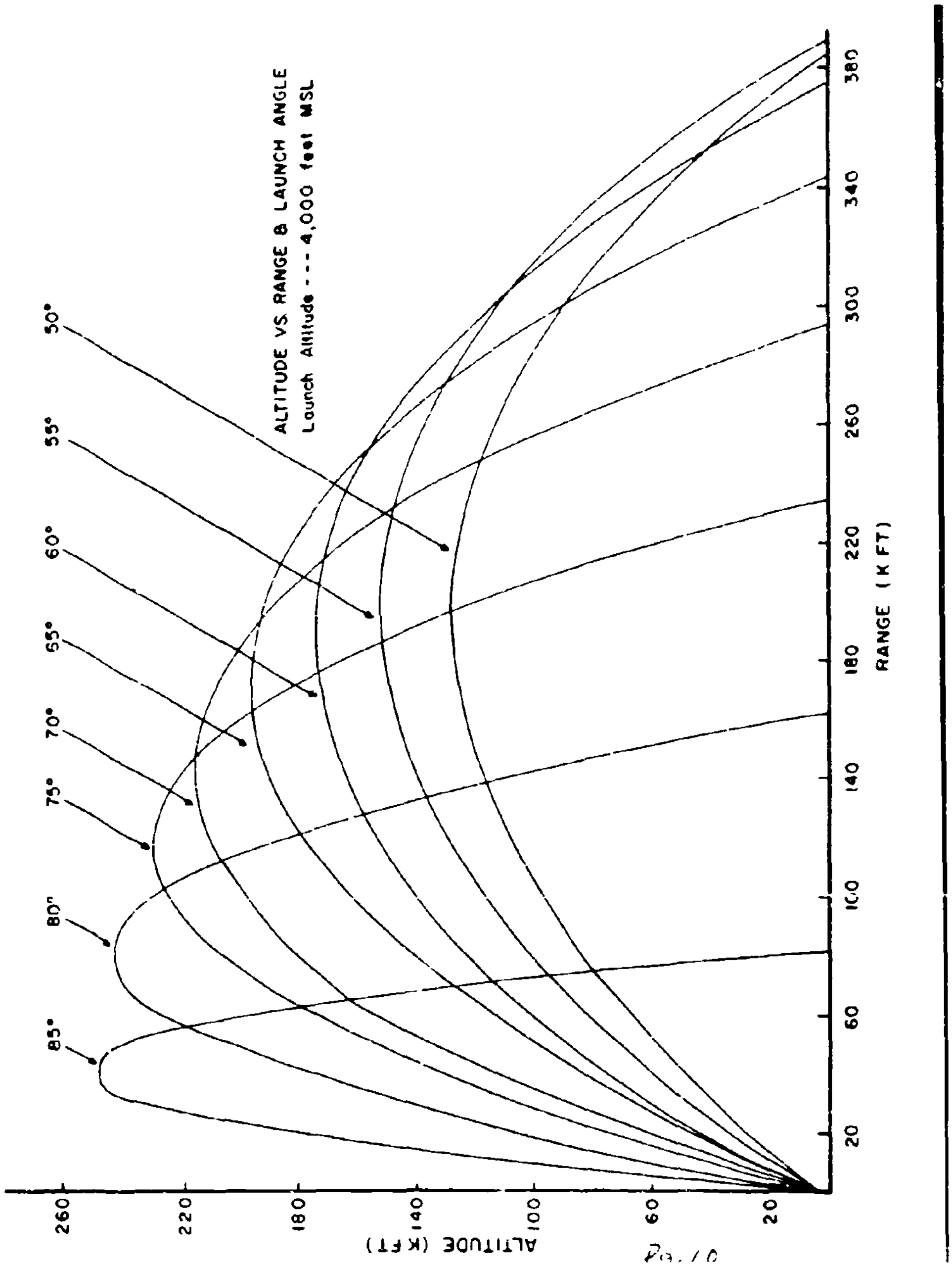

Figure 6 Nominal trajectories for the 5-inch gun-probe vehicle for selected QE's from a sea level elevation of 4000 feet msl (after McCluney).

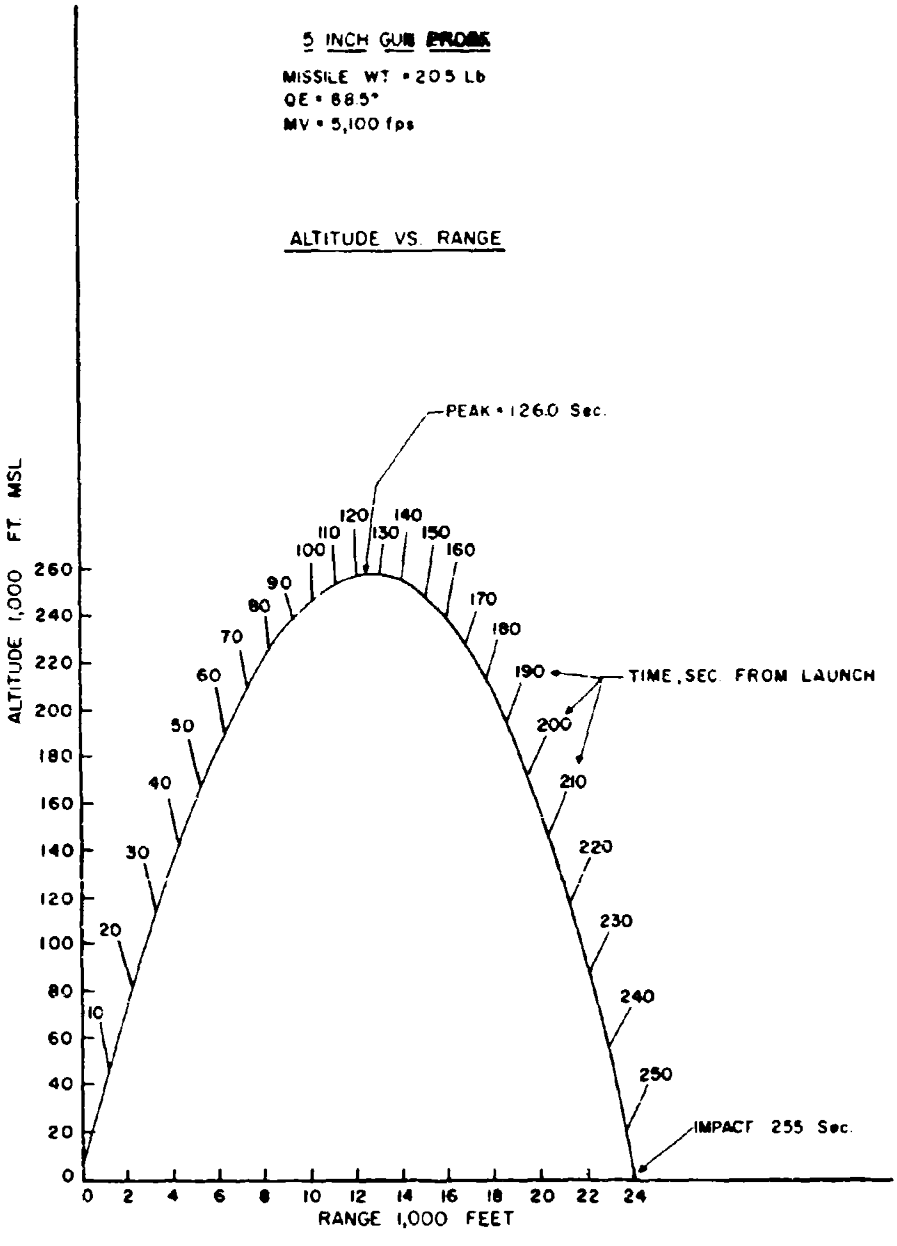

Figure 7 Nominal trajectory for the 5-inch gun-probe vehicle at WSMR. Note that the high QE (88.5) limits the range requirements to 24,000 ft.

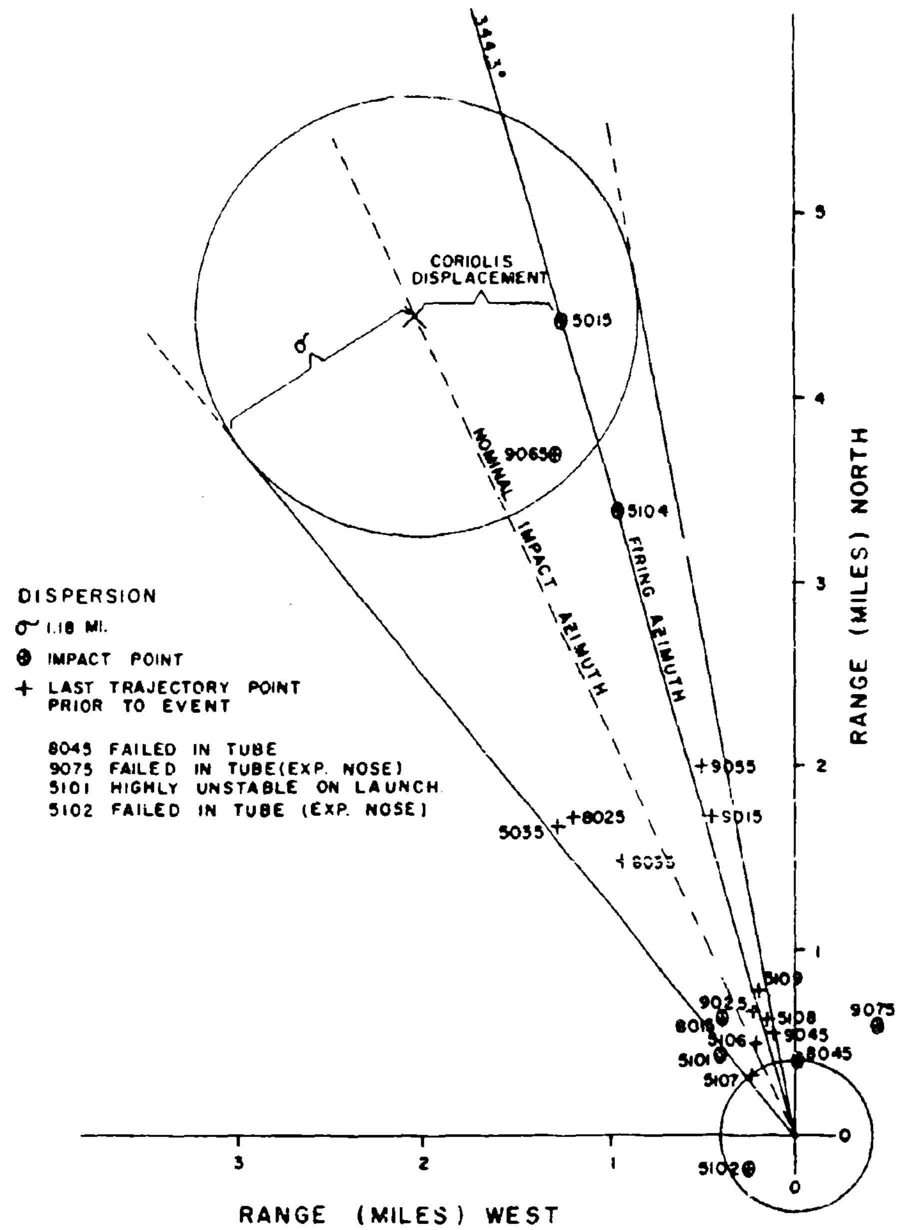

Figure 8 Impact and dispersion data for several gun-probe rounds fired at White Sands. Note that all rounds that impacted outside the nominal impact zone were not successfully launched.

DISPERSION AND NOMINAL TRAJECTORIES

Fig. 6 shows nominal trajectories of the 5-inch gun-probe vehicle launched from 4000 feet above seal level for several QE's. Fig. 7 is a trajectory of the 5-inch gun-probe vehicle for an 88.5° QE. It is noted that the impact range is only 4.5 mi. Combined with the 2σ dispersion[7] data of 2.36 miles, this defines a nominal impact and dispersion area of conical shape less than 2.5 miles wide at its maximum width and approximately 5 miles in length. A QE of 88.5° has has been used at WSMR for 19 flights, and each stable flight has impacted within this zone (Fig. 8). Structural failure and flight instability have required a larger experimental safety range.

APPLICATIONS

While the major application of the 5-inch gun system is anticipated to be in stratospheric and mesospheric sounding, other significant uses are planned. The application of the gun system for placement of specific nonmeteorological payloads at desired points in space has also been investigated. As mentioned earlier, an acoustic source payload has been packaged and successfully flown to acquire acoustic-atmospheric data. This payload also serves as an optical point source for other studies. There is also a desire to refine the system for low altitude soundings at great horizontal distances for application in remote or inaccessible areas, i.e., coasts, geographically restricted or forbidden territory.

CONCLUSION

It is evident that the perfection of the gun-launched atmospheric sounding system will provide a new, versatile mechanism for obtaining remote atmospheric data. This system can be used at existing sounding sites, and will open potential opportunities for new sounding sites heretofore prohibited by extensive and expensive range requirements.

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DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) U. S. Army Electronics Command Fort Monmouth, New Jersey	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

Gun-Launched Vertical Probes at White Sands Missile Range

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (Last name, first name, initial)

Williamson, L. Edwin

6. REPORT DATE February 1966	7a. TOTAL NO. OF PAGES 22	7b. NO. OF REFS 7
8a. CONTRACT OR GRANT NO. b. PROJECT NO. DA Task 1V650212A127-03 d.	9a. ORIGINATOR'S REPORT NUMBER(S) ECOM - 5030 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	

10. AVAILABILITY/LIMITATION NOTICES

Qualified requesters may obtain copies of this report from DDC.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY U. S. Army Electronics Command Atmospheric Sciences Laboratory White Sands Missile Range, New Mexico

13. ABSTRACT

The status of the gun-launched projectile system as a stratospheric sensor vehicle is discussed. The report is based on data obtained at White Sands Missile Range, and at Wallops Island, Virginia, where tests of recently developed hardware show an altitude-obtaining success of nearly 100 percent. The report reviews the fundamentals of the system, including launcher and propulsion techniques, the flight vehicle, and the payload and expulsion system. It is pointed out that the dispersion characteristics of this vehicle offer new potential for high altitude soundings at sites having limited real estate.

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